

APPENDIX A

MONITORING PARAMETERS AND DATA INTERPRETATION

PARAMETER SUMMARY

Upon receiving the regional report, please read the *VLAP Water Quality Data Interpretation* section carefully. Current and historical water quality trends are described on an individual and regional basis. This Appendix serves to supplement the report by providing detailed descriptions of the chemical and biological data collected through VLAP, as well as helps understand the data interpretation section.

In the *VLAP Water Quality Data Interpretation* section, the epilimnetic deep spot data are compared to the respective New Hampshire median to provide an understanding of how the quality of your lake deep spot compares to other New Hampshire lake deep spots. Table 1 summarizes key biological, chemical, and physical parameters for all the state's lakes surveyed since 1976.

Table 1. Summer Epilimnetic Values of New Hampshire Lakes

| Parameter | #* | Minimum | Maximum | Mean | Median |
|------------------------------------|-----|---------|---------|-------|--------|
| pH (units) | 780 | 4.3 | 9.3 | 6.5** | 6.6 |
| Alkalinity (mg/L) | 781 | -3.0 | 85.9 | 6.6 | 4.9 |
| Total Phosphorus (ug/L) | 772 | < 1 | 121 | - | 12 |
| Conductivity (uMhos/cm) | 768 | 13.1 | 696.0 | 59.4 | 40.0 |
| Chloride (mg/L) | 742 | < 2 | 198 | - | 4 |
| Chlorophyll-a (mg/m ³) | 776 | 0.19 | 143.8 | 7.16 | 4.58 |
| Transparency (m)*** | 663 | 0.40 | 13.0 | 3.7 | 3.2 |

* = the number of lake stations sampled

** = average pH reading; not average of hydrogen ion concentration

*** = does not include "visible on bottom" readings

Chlorophyll-*a*

Algae, also referred to as phytoplankton, are photosynthetic plants that contain chlorophyll-*a* but do not have true roots, stems, or leaves. They do, however, grow in many forms such as aggregates of cells (colonies), in strands (filaments), or as microscopic single cells. They may also be found growing on objects, such as rocks or vascular plants, on the lake bottom or free-floating in the water column. Regardless of their form, these primitive plants carry out photosynthesis and accomplish two very important roles in the process. First, they convert non-living compounds into organic, living, matter. These tiny plants form the base of a lake food chain. Microscopic animals, also known as zooplankton, graze upon algae like cows graze on grass in a field. Fish also feed on algae. Second, the water is oxygenated, aiding the chemical balance and biological health of the lake system.

Algae require sunlight, nutrients, and certain temperatures to thrive. All of these factors are constantly changing in a lake on a daily, seasonal, and yearly basis. Therefore, algal populations and the abundance of individual algal species naturally change in composition and distribution with changes in weather or lake quality. VLAP uses the measure of chlorophyll-*a* as an indicator of algal abundance. Algae are microscopic plants that contain the green pigment chlorophyll; the concentration of chlorophyll-*a* measured in the water gives an estimation of the algal concentration. If the chlorophyll-*a* concentration increases, this indicates an increase in the algal population.

Generally, a chlorophyll-*a* concentration of less than 3.3 mg/m³ typically indicates water quality conditions that are representative of oligotrophic lakes, while a chlorophyll-*a* concentration greater than or equal to 5 mg/m³ indicates eutrophic lakes. A chlorophyll-*a* concentration greater than or equal to 11 mg/m³ generally indicates an undesirable reproduction of algae, or what is generally referred to as an algal bloom, is occurring.

Table 2. Guidance Levels for NH Lake Chlorophyll-*a* Concentrations

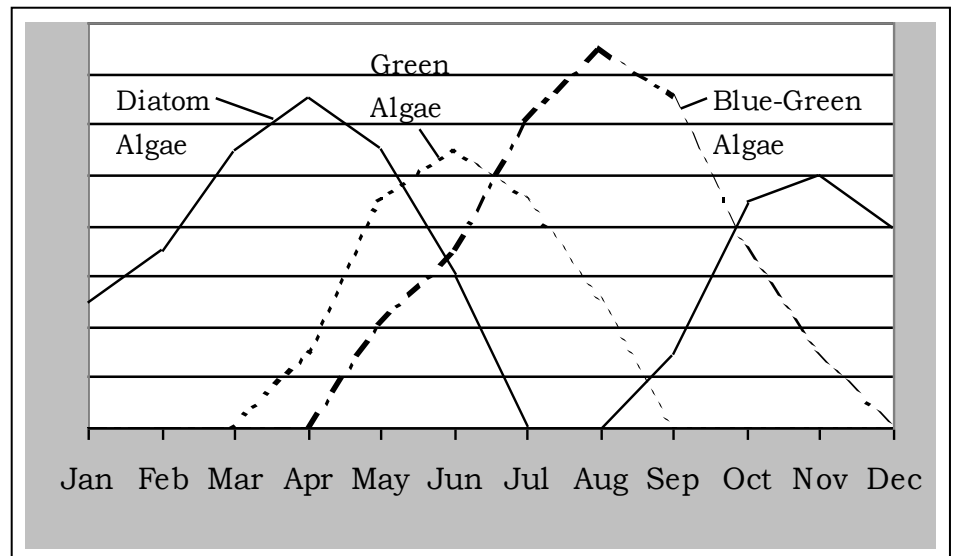
| Category | Chlorophyll-<i>a</i> (mg/m³) |
|---------------------|------------------------------------------------|
| Good | 0.0 – 5 |
| More than desirable | 5.1 – 11 |
| Nuisance amounts | > 11 |

Phytoplankton

The type of phytoplankton (algae) and/or cyanobacteria present in a lake can be used as an indicator of general lake quality. The most direct way to obtain this information is to collect a plankton sample at the deep spot using a plankton net, count the quantity of phytoplankton and cyanobacteria contained in the sample, and identify the genera present in the sample using a microscope. An abundance of cyanobacteria (blue-green algae), such as *Anabaena*, *Aphanizomenon*, *Oscillatoria*, or *Microcystis* may indicate an excessive phosphorus concentration or that the lake ecology is out of balance. On the other hand, diatoms such as *Asterionella*, *Synedra*, and *Tabellaria* or golden-brown algae such as *Dinobryon* or *Chrysosphaerella*, are typical phytoplankton found in New Hampshire's less productive lakes. In shallow warm waters with minimal wave action such as a cove, filamentous green algae may grow and form what looks like a mass of green cotton candy.

Phytoplankton populations undergo a natural **succession** during the growing season. Many factors influence this succession: amount of sunlight, availability of nutrients, temperature of the water, and the amount of zooplankton grazing. As shown in the diagram on the next page, it is natural for diatoms to be the dominant phytoplankton in the spring and then green algae in the early summer, while cyanobacteria may dominate in mid to late summer. The phytoplankton samples collected will show different dominant species, depending on when the samples were collected.

Figure 1. A Typical Seasonal Succession of Lake Algae



Phytoplankton Groups and Genera Common to New Hampshire Lakes and Ponds

Greens (Chlorophyta)

Ankistrodesmus
Arthrodesmus
Cosmarium
Elakotothrix

Eudorina
Kirchneriella
Dictyosphaerium
Mougeotia

Pandorina
Pediastrum
Quadrigula
Sphaerocystis

Spirogyra
Staurastrum
Scenedesmus
Ulothrix

Diatoms (Bacillariophyta)

Asterionella
Cyclotella

Melosira
Fragilaria

Rhizosolenia
Surirella

Synedra
Tabellaria

Dinoflagellates (Pyrrophyta)

Ceratium

Peridinium

Gymnodinium

Cyanobacteria (Cyanophyta)

Anabaena
Aphanizomenon

Chroococcus
Coelosphaerium

Gloeotrichia
Lyngbya

Microcystis
Oscillatoria

Golden-Browns (Chrysophyta)

Chrysosphaerella

Dinobryon

Mallomonas

Synura

Uroglenopsis

Cyanobacteria

Cyanobacteria are bacterial microorganisms that photosynthesize. Cyanobacteria may accumulate to form surface water scums. They produce a blue-green pigment but may impart a green, blue, or pink color to the water. Cyanobacteria are some of the earliest inhabitants of our waters, and they are naturally occurring in New Hampshire lakes. They are part of the aquatic food web and can be eaten by various grazers in the lake ecosystem, such as zooplankton and mussels. Research indicates that cell abundance increases as in-lake phosphorus levels increase.

Although they are most often seen when floating near the lake surface, many cyanobacteria spend a portion of their life cycle on the lake bottom during the winter months as akinetes. As spring provides longer periods of sunlight and warmer temperatures, cyanobacteria move up the water column and eventually rise toward the surface where they can form dense scums, often seen in mid to late summer and, weather permitting, sometimes well into the fall.

Certain cyanobacteria species produce toxins that adversely affect livestock, domestic animals, and humans. According to the World Health Organization (WHO), toxic cyanobacteria are found worldwide in both inland and coastal waters. The first reports of toxic cyanobacteria in New Hampshire occurred in the 1960s and 1970s. During the summer of 1999, several dogs died after ingesting toxic cyanobacteria from Lake Champlain in Vermont. The WHO has documented acute impacts to humans from cyanobacteria from the U.S. and around the world as far back as 1931. While most human health impacts have resulted from ingestion of contaminated drinking water, cases of illnesses have also been attributed to swimming in cyanobacteria infested waters.

The possible effects of cyanobacteria on the “health” of New Hampshire lakes and their natural inhabitants, such as fish and other aquatic life, are under study at this time. The Center for Freshwater Biology (CFB) at the University of New Hampshire (UNH) is currently examining the potential impacts of these toxins upon the lake food web. The potential human health hazards via exposure through drinking water and/or during recreational water activities are also a concern to toxicologists throughout the world.

Cyanobacteria occur in all lakes, everywhere. In New Hampshire, there are several common cyanobacteria that include: *Gleotrichia*, *Merismopedia*, *Anabaena*, *Aphanizomenon*, *Oscillatoria*, *Coelosphaerium*, *Lyngbya*, and *Microcystis*. *Anabaena* and *Aphanizomenon* produce **neurotoxins** that interfere with nerve function and have almost immediate effects when ingested. *Microcystis* and *Oscillatoria* are best known for producing **hepatotoxins** known as microcystins, which affect liver function. *Oscillatoria* and *Lyngbya* produce **dermatotoxins** which cause skin rashes.

Both DES and UNH have extensive lake monitoring programs. Generally, the water quality of New Hampshire’s lakes is very good. However, DES strongly advises against using lake water for consumption, since neither in-home water treatment systems nor boiling the water will eliminate cyanobacteria toxins if they are present. If you observe a well-established potential cyanobacteria bloom or scum in the water, please adhere to the following:

- Do not wade or swim in the water!
- Do not drink the water or let children drink the water!
- Do not let pets or livestock into the water!

Exposure to toxic cyanobacteria may cause various symptoms, including nausea, vomiting, diarrhea, mild fever, skin rashes, eye and nose irritations, and general malaise. If anyone comes in contact with a dense cyanobacteria scum, they should rinse off with fresh water as soon as possible.

If you observe a Cyanobacteria scum, please call the cyanobacteria hotline at 419-9229. DES will sample the scum and determine if it contains cyanobacteria that are associated with toxin production. An advisory or warning will be issued indicating that the area may not be suitable for swimming. DES will issue a press release and will notify the town health officer, beach manager, and/or property owner, and the New Hampshire Department of Health and Human Services. DES will continue to monitor the water and will notify the appropriate parties regarding the results of the testing. When monitoring indicates that cyanobacteria are no longer present at levels that could harm humans or animals, the advisory will be removed

Transparency

The Secchi Disk is a 20 centimeter disk with alternating black and white quadrants. It has been used since the mid-1800s to measure the transparency, or clarity, of water. The Secchi Disk is named after the Italian professor P.A. Secchi whose early studies established the experimental procedures for using the disk. Transparency, a measure of the water clarity, is affected by the amount of algae, color, and particulate matter within a lake. In addition, the transparency reading may be affected by wave action, sunlight, and the eyesight of the volunteer monitor.

Therefore, it is recommend that two or three monitors view the Secchi Disk while sampling, and then average all the measurements. DES recommends that all volunteer groups collect transparency readings with and without the use of a viewscope. A comparison of the transparency readings taken with and without the use of a viewscope indicates that the use of a viewscope typically increases the depth to which the Secchi Disk can be seen, particularly on sunny and windy days. The use of the viewscope results in less variability in transparency readings between monitors and between sampling events.

In general, a transparency greater than 4.5 meters indicates oligotrophic conditions, while a transparency of less than 2 meters is indicative of eutrophic conditions. The median transparency for New Hampshire lakes is 3.2 meters and the mean transparency is 3.7 meters.

Table 3. Guidance Levels for NH Lake Transparency

| Category | Transparency (m) |
|-----------------|-------------------------|
| Poor | < 2.0 |
| Good | 2.0 – 4.5 |
| Exceptional | > 4.5 |

Total Phosphorus

Like every living organism, lakes age over time. Lake aging is the natural process by which a lake fills-in over thousands of years. Lakes fill-in with erosional materials carried in by rivers and streams, with materials deposited directly through the air, and with materials produced in the lake itself. From the time a lake is created, the aging process begins. Although many New Hampshire lakes have the same chronological age, they fill-in at different rates due to differences in lake depth and size and individual watershed characteristics.

Eutrophication is the term used to describe lake aging that is accelerated by the process of increased nutrient input to a lake. Lakes can age more quickly than they would naturally due to human impacts, a process called cultural eutrophication. This accelerated aging results from watershed activities that increase nutrient loading and/or the deposition of other debris, such as fertilizing lawns, converting forest or pasture to cropland, and creating new impervious areas such as rooftops, parking lots, and driveways. Studies in New Hampshire have shown that phosphorus exports from agricultural lands is at least five times greater than from forested lands, and in urban areas may be more than 10 times greater than from forested lands.

The key nutrient in the eutrophication process is phosphorus. Phosphorus is the limiting nutrient in New Hampshire lakes; the greater the phosphorus concentration in a lake, the greater the biological production. Phosphorus sources within a lake's watershed include septic system effluent, animal waste, lawn fertilizer, eroding roadways and construction sites, natural wetlands, and atmospheric deposition. Reducing the amount of phosphorus in a lake will typically result in reduced algal concentrations.

A deep spot epilimnetic (upper layer) phosphorus concentration of less than 8 ug/L typically indicates oligotrophic conditions, while an epilimnetic concentration greater than 28 ug/L is indicative of eutrophic conditions. The median phosphorus concentration in the epilimnion of New Hampshire lakes is 12 ug/L. The median phosphorus concentration in the hypolimnion is 14 ug/L.

Table 4. Guidance Levels for Epilimnetic Total Phosphorus Concentrations

| Category | Total Phosphorus (ug/L) |
|---------------------|--------------------------------|
| Ideal | < 8 |
| Average | 8.1 – 12 |
| More than desirable | 12.1 – 28 |
| Excessive | > 28 |

Dissolved Oxygen and Temperature

The presence of dissolved oxygen is vital to bottom-dwelling organisms as well as fish and amphibians. If the concentration of dissolved oxygen is low, typically less than 5 mg/L, species intolerant, meaning sensitive, to low oxygen levels, such as trout, will be forced to move up closer to the surface where there may be more dissolved oxygen but the water temperature is generally warmer, creating additional stress on the species.

Water temperature is also a factor in the dissolved oxygen concentration. Water can hold more oxygen at colder temperatures than at warmer temperatures. Therefore, a lake will typically have a higher concentration of dissolved oxygen during the winter, spring, and fall than during the summer. At least once during each summer, a DES biologist measures the dissolved oxygen and temperature at set intervals from the bottom of the lake to the surface. These measurements allow us to determine the extent of thermal stratification as well as the lake oxygen content.

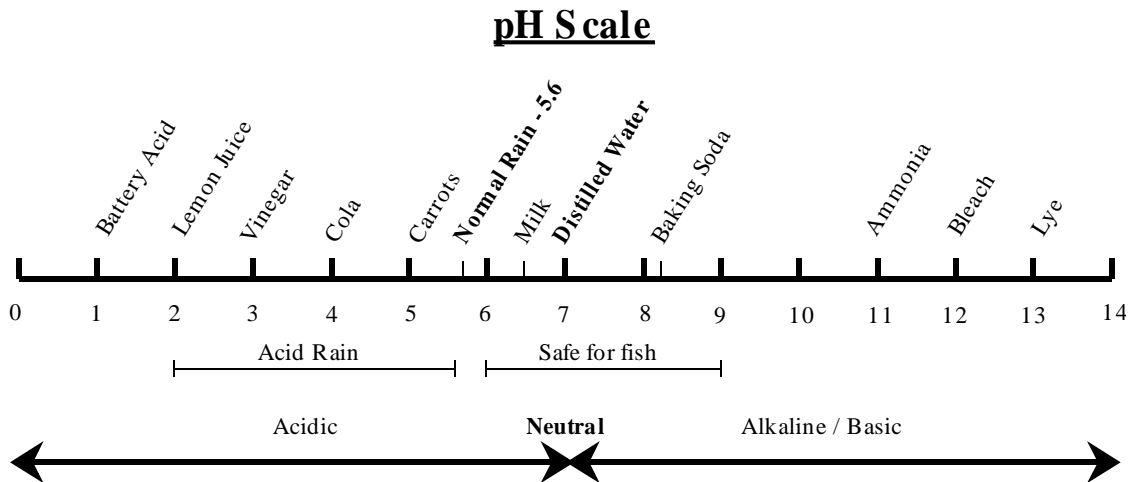
Lakes that are thermally stratified and are more productive tend to experience a decrease in dissolved oxygen in the deep hypolimnion layer as summer progresses. This process is driven by bacteria in the lake sediments. The bacteria decompose the dead, organic matter that settles out of the water column. The decomposition process utilizes oxygen and results in oxygen depleted bottom waters. More productive lakes tend to have organic-rich sediments leading to greater decomposition and potentially creating a severe dissolved oxygen deficit of less than 1 mg/L.

Low oxygen conditions can then trigger phosphorus that is normally bound to the sediment to be released back into the water column, a process called internal phosphorus loading. Internal phosphorus loading can be reflected in elevated phosphorus concentrations in hypolimnetic waters. Once lake mixing occurs (fall), phosphorus-rich hypolimnetic waters are re-distributed throughout the water column and can stimulate additional algal and/or cyanobacteria growth.

The dissolved oxygen percent saturation shows the percentage of oxygen that is dissolved in the water at a particular temperature and depth. Typically, during the summer, the percent saturation is lower in the deep hypolimnion layer due decomposition occurring at the lake bottom. A high reading at or slightly above the thermocline may be due to a layer of algae or cyanobacteria, producing oxygen during photosynthesis. Colder water is generally able to hold more dissolved oxygen than warmer water and generally, the deeper the water, the colder the temperature. As a result, a reading of 9 mg/L of oxygen at the warm lake surface will yield a higher percent saturation than a reading of 9 mg/L of oxygen at 25 meters where the water is much cooler.

pH

pH is measured on a logarithmic scale of 0 to 14. The lower the pH the more acidic the solution, due to higher concentrations of hydrogen ions. Acid rain typically has a pH of 3.5 to 5.5 due to pollutants added from the air. In contrast, the median pH for New Hampshire lakes is 6.6.



Lake pH is important to the survival and reproduction of fish and other aquatic life. A pH below 5.0 severely limits the growth and reproduction of fish. A pH between 6.0 and 7.0 is ideal. Many lakes exhibit lower pH values in the deeper waters than nearer the surface. This effect is greatest in the bottom waters of a thermally stratified lake. Decomposition carried out by bacteria in the lake bottom causes the pH to drop, while photosynthesis by phytoplankton in the upper layers causes the pH to increase. Tannic and humic acids released into the water by decaying plants can create more acidic waters particularly in areas influenced by wetlands. After the spring-time snow melt or a significant rain event, surface waters may have a lower pH than deeper waters and may take several weeks to recover, since snowmelt and rainfall typically have pH values of 5 or lower.

Table 5. Guidelines levels for NH Lake pH

| Category | pH (units) |
|----------------------------------------------|------------|
| Critical (toxic to most fish) | < 5.0 |
| Endangered (toxic to some aquatic organisms) | 5.1 – 6.0 |
| Satisfactory | > 6.0 |

Acid Neutralizing Capacity

Buffering capacity or acid neutralizing capacity (ANC) describes the ability of the lake to resist changes in pH by neutralizing acidic inputs. The higher the ANC, the greater ability the lake has to neutralize acidic inputs. This concept can be compared to a person taking an antacid to neutralize stomach acid indigestion. Low ANC lakes are not well-buffered. These lakes are often adversely affected by acidic inputs. Historically, New Hampshire has had naturally low ANC waters because of the prevalence of granite bedrock. Granite contains only a small amount of buffering elements such as calcium.

The median ANC for New Hampshire lakes is 4.9 mg/L while the mean ANC is 6.6 mg/L. This relatively low value makes surface waters vulnerable to the effects of acid precipitation.

Table 6. Guidelines for NH Lake Acid Neutralizing Capacity

| Category | ANC (mg/L) |
|-----------------------|-------------------|
| Acidified | < 0.0 |
| Extremely Vulnerable | 0.1 – 2.0 |
| Moderately Vulnerable | 2.1 – 10.0 |
| Low Vulnerability | 10.1 – 25.0 |
| Not Vulnerable | > 25.0 |

Conductivity

Conductivity is the numerical expression of the ability of water to carry an electrical current. It is determined primarily by the number of ionic particles present. The soft waters of New Hampshire have traditionally low conductivity values, generally less than 50.0 uMhos/cm. However, specific categories of good and bad levels cannot be constructed for conductivity because variations in watershed geology can result in natural fluctuations in conductivity.

Generally, values in New Hampshire lakes exceeding 100 uMhos/cm indicate cultural, meaning human, disturbances. An increasing conductivity trend typically indicates the presence of point source and/or non-point sources of pollution in the watershed. The median conductivity for New Hampshire lakes is 40.0 uMhos/cm while the mean conductivity is 59.4 uMhos/cm.

Chloride

The chloride ion (Cl-) is found naturally in some surface and ground waters and in high concentrations in seawater. Higher-than normal chloride concentrations in freshwater, typically sodium chloride, that is used on foods and present in body wastes, can indicate sewage pollution. The use of highway deicing salts can also introduce chlorides to surface or ground waters.

Although chloride can originate from natural sources, most of the chloride that enters the environment in New Hampshire is associated with the storage and application of road salt. Road salt, which is most often sodium chloride, readily dissolves and enters aquatic environments in ionic forms. As such, chloride-containing compounds commonly enter surface water, soil, and ground water during late-spring snowmelt since the ground is frozen during much of the late winter and early spring.

Chloride ions are conservative, which means that they are not degraded in the environment and tend to remain in solution, once dissolved. Chloride ions that enter ground water can ultimately be expected to reach surface water and, therefore, influence aquatic environments and humans. Research has shown that elevated chloride levels can be toxic to freshwater aquatic life. Among the species tested, freshwater aquatic plants and invertebrates tend to be the most sensitive to chloride. In order to protect freshwater aquatic life in New Hampshire, the state has adopted acute and chronic chloride water quality standards of 860 and 230 mg/L, respectively, for surface waters. The chloride content in New Hampshire lakes is naturally low (median = 4 mg/L) in surface waters located in remote areas away from habitation. Higher values are generally associated with salted roadways and, to a lesser extent, with septic inputs.

Turbidity

Turbidity in water is caused by suspended matter, such as clay, silt, and algae that cause light to be scattered and absorbed, not transmitted in straight lines through the water. Secchi Disk transparency, and therefore water clarity, is strongly influenced by turbidity. High turbidity readings are often found in water adjacent to construction sites; during rain events unstable soil erodes and causes turbid water downstream. Also, improper sampling techniques, such as hitting the bottom of the lake with the Kemmerer bottle or stirring up the stream bottom when collecting tributary samples, may also cause high turbidity readings. The New Hampshire median for lake turbidity is 1.0 NTU.

Table 7. Statistical Summary Levels for NH Lake Turbidity

| Category | Value (NTU) |
|-----------------|--------------------|
| Minimum | < 0.1 |
| Maximum | 22.0 |
| Median | 1.0 |

Bacteria

Surface waters contain a variety of microorganisms including bacteria, fungi, protozoa, and algae. Most of these occur naturally and have little or no impact on human health. Health risks associated with water contact occur generally when there is contamination from human sources or other warm blooded animals. Contamination arises most commonly from sources of fecal waste such as failing or poorly designed septic systems, leaky sewage pipes, nonpoint source runoff from wildlife habitat areas, or large congregations of waterfowl.

Swim beaches with heavy use, shallow swim areas, and/or poor water circulation also have commonly reported bacteria problems. Therefore, water used for swimming should be monitored for indicators of possible fecal contamination. Contamination is typically short-lived since most bacteria cannot survive long in surface waters as their natural environment is the gut of warm blooded animals. However, a recent study has shown that *E. coli* can survive fairly long periods of time in the sediments.

Specific types of bacteria, called indicator organisms, are the basis of bacteriological monitoring, because their presence indicates that sources of fecal contamination exist. Indicators estimate the presence and quantity of things that cannot easily be measured individually. We measure these sewage or fecal indicators rather than the pathogens themselves to estimate sewage or fecal contamination and, therefore, the possible risk of disease associated with using the water.

New Hampshire closely follows the bacteria standards recommended by the U.S. Environmental Protection Agency (EPA). Following a 1988 EPA report recommending the use of *Escherichia coli* (*E.coli*) as a standard for public water supplies and human contact, DES followed suit by adopting *E.coli* as the indicator organism. The standards for Class B waters specify that no more than 406 *E. coli* counts/100 mL, or a geometric mean based on at least three samples obtained over a 60 day period, be greater than 126 *E. coli* counts/100 mL. Designated public beach areas and other Class A waters, have more stringent standards: 88 *E. coli* counts/100 mL in any one sample, or a geometric mean of three samples over 60 days of 47 *E. coli* counts/100 mL.